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Secretary of the Council—H. W. Springsteen, Western Reserve University.

JOHN ZELENY,
General Secretary

THE WORK OF THE ELECTRICAL DIVISION OF THE BUREAU OF STANDARDS[1]

1. INTRODUCTION

THE Bureau of Standards has grown considerably, both in equipment and personnel, since its inception in 1901. The original staff of fourteen has increased to nearly three hundred, and the material equipment has been augmented in a similar ratio. Its functions also have developed, although authority for all its manifold activities is contained in the brief act of Congress of March 3, 1901, which established the Bureau, and its growth has been closely along the lines laid down by the director in his first announcements of the policy of the new bureau.

The name Bureau of Standards does not signify to the average person the wide scope of the work of the bureau, which is really a national physical, chemical and engineering laboratory. In Germany there are three similar national institutions, and the establishment of a fourth has been proposed; these four combined would cover the field occupied in this country by the Bureau of Standards. The German institutions referred to are the Physikalisch-Technische Reichsanstalt, for physics; the Normal Eichungs-Kommission, for weights and measures, and the Material Prufungs Amt, for engineering and the testing of materials. In addition to these three institutions, which have been in active operation for many years, a royal chemical institute for chemistry has been for some time under consideration. In England the National Physical Laboratory occupies a field more nearly like that of the Bureau of Standards, but the Board of Trade divides with it some of these functions.

[1] Address of the vice-president and chairman of Section B, Washington, 1911.

The work of the Bureau of Standards is distributed among seven divisions, as follows:

I. Electricity and photometry.
II. Weights and measures.
III. Heat and thermometry.
IV. Optics.
V. Chemistry.
VI. and VII. Engineering and the testing of materials.

Thus, it will be seen that the work of Divisions I., III. and IV. correspond to that of the Reichsanstalt of Germany, and the remaining four divisions to the other three German institutions mentioned above.

The work of the bureau may be broadly divided into two parts, research and testing, although much time is devoted to the preparation of specifications, the standardization of practise and the diffusion of information that does not fall under either of these heads. To undertake to describe the work of research, testing and standardization carried on in all the divisions of the bureau would be a task requiring more time than is at present available. I shall, therefore, limit myself to the work of Division I., and if I succeed in bringing to your minds a full appreciation of the character and importance of the work we are trying to do in electricity, magnetism and photometry, you may take this when

multiplied by six as standing for the work of the bureau as a whole.

2. SCIENTIFIC INVESTIGATIONS

The scientific researches which have been carried out in the electrical division, the results of which are contained in more than 100 papers published in the *Bulletin* of the bureau, may be grouped under the following five heads.

(*a*) *Theory of Electrical Measurements and of Absolute Instruments.*—One of the first things that demanded attention when the bureau was established was the fixing and maintaining of the standards for electrical measurements, and the choice and development of methods of measurement. This has involved a thorough study of the theory of electrical measurements, and of the theory of the absolute instruments which are employed in the various kinds of absolute electrical measurements. Such studies naturally led to new methods and to the improvement of existing methods, and to a better knowledge of the theory of electrical measurements and of electrical instruments. The *Bulletin* contains twenty-seven papers under this head, including such subjects as the calculation of self and mutual inductance of the various kinds of coils used in the absolute instruments employed in the measurement of resistance and current in C.G.S. units, and in many other kinds of measuring instruments; the theory of different kinds of electrodynamometers, and of a new method for the absolute measurement of resistance; theory of coupled circuits and other problems in wireless telegraphy, and the preparation of a complete list of formulæ for use in calculating inductances of almost every kind of electric circuit.

(*b*) *Methods of Electrical Measurement.*—In the work of electrical testing and research much attention was given to improving methods of measurement, and the *Bulletin* contains thirty-three papers on this subject, including the absolute measurement of inductance and of capacity, the measurement of inductance in terms of capacity by means of alternating currents, wattmeter methods of measuring power, the influence of wave form upon electrical instruments and upon hysteresis losses in iron, the measurement of energy losses in dielectrics, and in iron, a standard method of demagnetizing iron in measurements of magnetic induction, methods of testing transformer iron, measurement of the ratio of transformation and of phase relations in current and potential transformers, quantitative measurements in radio-telegraphic circuits and experiments with high frequency circuits and various papers on methods of measurement in photometry.

(*c*) *Experimental Researches upon Concrete Electrical Standards.*—The results of absolute electrical measurements are preserved by means of concrete electrical standards, and the practical units of electrical measurements as defined and agreed to by international electrical congresses are expressed in terms of concrete electrical standards, and not in terms of the C.G.S. system. The accuracy attainable in absolute measurements and the definiteness of legal values are both limited by the constancy and reproducibility of the concrete standards by means of which they are expressed and preserved. The principal concrete standards are (1) the *mercury column,* the resistance of which defines the international ohm, and the *wire standards* to which values are assigned in terms of the mercury ohms; (2) the *silver voltameter* which defines the international ampere; and (3) the *Weston normal cell,* the concrete standard employed for the measurement of

electromotive forces, and the value of which is fixed in terms of the international ohm and the international ampere. These concrete standards were defined by the Chicago Electrical Congress of 1893. The principal countries of the world did not, however, adopt the Chicago specifications and numerical values unchanged, so that the international uniformity hoped for was not altogether realized. As the precision of electrical measurements increased and there came a demand for greater accuracy in electrical instruments, the old specifications became inadequate, and the differences in numerical values between different countries became more and more annoying. After attention had been drawn at St. Louis in 1904 to the need of a new international conference for the purpose of securing improved specifications for the concrete electrical standards and uniform numerical values for the same, and after a preliminary conference at Charlottenburg in 1905, in which the program for such an international conference was carefully considered, the conference was called by Great Britain, and met in London in October, 1908. Although considerable attention has been given to the subject of absolute electrical measurements and the preparation of the concrete electrical standards in the fifteen years between 1893 and 1908, it was found at the London Conference impossible to formulate complete specifications for the three primary electrical quantities, and impossible to agree upon a satisfactory value for the Weston normal cell, which latter was adopted at London in place of the Clark cell, as the official standard for expressing the value of the international volt. The discussion at the London Conference brought out clearly the inadequacy of a bulky international conference, sitting for a week or ten days once or twice in a generation, as a tribunal for settling wisely such technical questions as are involved in the specifications of electrical standards and fixing the values of the standard cells so that it would satisfy Ohm's law. It was recognized that this law could not be repealed or ignored, even by an international conference, and the best that could be done, therefore, was to choose a provisional value for the Weston cell (1.0184 volts at 20°) and to leave to an International Committee on Electrical Units and Standards, established by the London Conference for the purpose, the task of carrying on the investigations, completing the specifications, and finding a new and more precise value of the standard cell. This committee consisted of fifteen members and five associate members, representing eleven different countries, and during the three years that have elapsed since the London Conference it has encouraged investigations in the direction indicated, and has partly accomplished its task. While the committee as a whole has acted in the matter, the experimental work has been done chiefly by the national standardizing laboratories of England, France, Germany and the United States, and in this work the Bureau of Standards has been active.

It might appear that three years is ample time in which to settle all the questions necessary to the satisfactory completion of the work left undone by the London Conference, and so it would be if a reproducibility of one one-hundredth of one per cent. in the standards were deemed sufficient. But when we recall the constancy of the standards of length and mass, and the regularity of the earth as a standard timepiece, we can not be content with our concrete standards of resistance and electromotive force so long as uncertainties exist as great as a thousandth of one per cent. As the demands for greater

precision of measurement increase, the national standardizing laboratory must maintain so high a plane of excellence that those best qualified to judge have the fullest confidence in its fundamental standards and in the accuracy of its work. The endeavor to improve these standards is not merely a matter of doing patiently the same thing over and over again. It means a whole train of investigations, through which an intimate knowledge of the behavior of these standards is obtained, disturbing influences removed or taken account of, impurities in the materials eliminated, and measurements made with what a few years ago would have seemed almost impossible accuracy. The by-products of such researches are often of great value, and become useful in many other directions.

To illustrate, let me refer to the silver voltameter, the concrete standard of electric current. In 1908 it was believed by many that the chemistry of the Rayleigh voltameter was simple, and that the most recently published work upon it had cleared up a mystery of long standing, relative to the disagreement of the Rayleigh and Richards forms of voltameters. Further study at the Bureau of Standards showed complexities due to the presence of filter paper which astonished chemists, and three years of continuous work have not answered all the questions which have arisen as to the effect of traces of organic impurity or of traces of acid or alkali, in the salt, or slight variations in the physical condition of the anode, or the volume and concentration of the electrolyte, or the density of the current, or the influence of dissolved gases. In addition to excellent facilities for purifying materials and making chemical determinations, and an unsurpassed equipment for measuring the current and weighing the deposits, the microscope and ultramicroscope have been brought into service. And although the outstanding discrepancies are only a few thousandths of one per cent., we have not felt justified in closing the work until the voltameter as a scientific instrument should be as thoroughly understood as possible.

The construction of standard cells has been beset with similar difficulties. The preparation of the materials has been studied with great pains, and hundreds of cells have been set up and carefully studied. To test their portability, they have been carried from country to country and around the world, and even sent through the mails to Europe and elsewhere. To try to determine the source of small differences between different lots of cells, and between different cells of the same lot, one component at a time has been varied, and materials prepared at different times and in different countries have been used side by side. The result has been a considerable improvement in standard cells, so that for most purposes they are satisfactory, but as standards there is still room for improvement.

One reason for desiring more perfect concrete electrical standards is to facilitate absolute measurements. We now know the value of the absolute ampere better than the value of the absolute ohm, but during the next few years the absolute ohm will probably be realized as well as the absolute ampere now is. Our international electrical units are now so well fixed that one can measure electrical power in international watts with great accuracy. With a better knowledge of the absolute ohm, we shall be able also under proper conditions to measure electrical and mechanical power in watts or in absolute units by means of electrical instruments with high precision.

The work at the Bureau of Standards

on the absolute measurement of current, using an improved form of Rayleigh current balance, has been thorough and exhaustive. To obtain a final result reliable to two or three parts in a hundred thousand requires that all possible sources of error as great as a few parts in a million must be examined and taken into account. It would be impossible in this form of current balance to measure directly the dimensions of the coils with the required precision, and hence the constant of the instrument must be determined by electrical means without such direct measurements; and to detect and eliminate unsuspected errors, several sets of fixed coils and several different moving coils were prepared and used interchangeably, giving the equivalent of several balances. This, in fact, did reveal unsuspected sources of error, and although it greatly prolonged the investigation, it gave results far more trustworthy in the end. A similar story could be told of the work at the bureau on mercury ohms, and on the determination of the ratio of the electrical units.

These are some of the researches in connection with electrical standards, which together constitute the third group of investigations in Division I. of the bureau. Some of them are described in papers contained in the *Bulletin,* and some are in press, and some are not yet completed.

(*d*) *Improvements in Instruments and the Development of New Instruments.*—In addition to new instruments developed and improvements made in existing instruments employed in the absolute measurements mentioned above, many improvements have been made in electrical instruments used for other kinds of electrical measurements.

Some of these improvements have been adopted by American and foreign instrument makers, and some are embodied only in instruments in our own laboratories. Among these may be mentioned the following:

(1) The Bureau of Standards type of sealed resistance standard, which is used not only for resistances of highest precision in standardizing institutions, but also for precision standards in ordinary use.

(2) The Bureau of Standards chronograph, for measuring and recording with extreme precision the speed of a machine, as, for example, the speed of a dynamo for the purpose of obtaining the frequency of the current generated with highest precision. It is used on the new apparatus for the measurement of absolute resistance at the bureau, and in connection with the absolute measurement of capacity and inductance, and has been adopted by the National Physical Laboratory on the magnificent machine recently erected at Teddington.

(3) The direct reading potentiometers designed for rapid and accurate work in the measurement of current and voltage, which have been of great service in the work of the bureau, and would be more largely used outside if instrument makers had been quicker to appreciate their merits.

(4) The series of electrodynamometers for the measurement of alternating current and power, which can be calibrated by direct current and used on alternating. Their range is up to 1,000 amperes, and one recently constructed, but not yet fully installed, will have a range of 5,000 amperes. They are essentially instruments for the testing laboratory, and without them the bureau would have been unable to make many of the tests which have been successfully carried out.

(5) Important improvements have been made in instruments for the accurate comparison of resistance standards and the testing of resistance boxes, potentiometers,

etc. In photometry a number of instruments have been developed or improved, including an automatic recording mechanism, a direct reading scale, a universal rotator, an improved integrating photometer, a direct recorder for life test work, an efficiency meter, etc.

Many other examples of the kind may be cited. In every case, instrument makers and the public have the fullest access to all information concerning new instruments or improvements in old instruments.

(*e*) *Determining the Properties of Materials*.—The fifth class of scientific investigations concerns the measurement of the properties of materials. Most of the work of this kind is included under the head of testing, the materials tested being in most cases samples of larger lots. But in some cases the work is done to find the average properties of a certain kind of material for the purpose of establishing a standard, or of finding how one property depends upon another. Examples of this kind are the investigations on the mean resistivity and temperature coefficient of resistivity of commercial copper wire. Samples were obtained from many sources, both in America and Europe, and values obtained from measurements made by one of the largest manufacturers, whose instruments and standards had been verified by the bureau.

In this way a mean value was obtained for commercial copper which was made the basis of a new wire table, computed by the bureau at the suggestion of the American Institute of Electrical Engineers, and which they at once adopted in place of their own table. These investigations also brought out a new relation between the temperature coefficient of resistivity and the resistivity itself, so that knowing either of these quantities, the other becomes known.

Another important investigation of this kind recently undertaken is on the relation between the magnetic and mechanical properties of iron and steel, with a view of ascertaining whether it is practicable to test materials for mechanical flaws by magnetic methods. Many investigations on the properties of materials employed in electrical work are needed to answer the hundreds of questions constantly arising, and some of these will soon be undertaken in cooperation with one of the committees of the American Society for the Testing of Materials.

3. ENGINEERING INVESTIGATIONS

In addition to work of the character just described under the head of scientific investigation, laboratory and field work have been conducted on several important practical questions, which may be mentioned under the head of engineering investigations.

One of these had to do with the use of electricity in mines, and the work was undertaken for the purpose of formulating a set of rules suitable for enacting into law, or that could be utilized in revising existing laws, concerning the safe use of electricity for light, power and signals in mines. A careful study of coal mines using electricity, and of the regulations of European and other countries concerning the use of electricity in mines, was made, a great many mining engineers, mine inspectors, mine superintendents and manufacturers of mining machinery were consulted, and the results embodied in a publication on the "Standardization of Electrical Practise in Mines."

Another investigation still in progress has to do with the state and municipal control of the manufacture and sale of illuminating gas. The bureau has been making a thorough study of the methods of testing

illuminating gas for chemical purity, and for its heating and illuminating value. This has involved an investigation of the methods of testing gas and of the instruments employed in such tests. That is, of apparatus used or that may be used in testing for hydrogen sulphide, total sulphur, ammonia, etc.; of gas calorimeters and of gas photometers and flame photometric standards. In connection with this the bureau has made a thorough study of the legal requirements in all the cities and states of the country and of the methods of testing and inspection in use, and has tried to formulate the results of these studies in such a way as to be useful in framing municipal ordinances or state laws on this subject. In this investigation a great deal of field work has been done, and some of the ablest and most experienced gas engineers and city and state inspectors and members of public service commissions have cooperated with the bureau. The results of this investigation, which has already been in progress for more than two years, will be published in two bulletins, one on the specifications of different kinds of illuminating gas and the public regulation of its distribution and sale, and the other on the methods of testing of gas and gas meters. In this work, three of the divisions of the bureau have cooperated.

Another investigation of great engineering importance is that of the effects of stray earth currents (due generally to street railways) upon the corrosion of gas and water pipes and of reinforced concrete structures. Experiments show that under certain circumstances such effects are not only real but serious. The bureau is doing a good deal of field work, as well as laboratory work on this subject, in order to learn the conditions under which the damage is greatest, and how best to remedy the trouble. The first public report of this work was made recently at the annual meeting of the American Gas Institute, and believing the bureau's work to be of great practical value, the institute voted to appoint a committee to cooperate with the bureau, and expressed the hope that the American Street Railway Association would do the same. Closely associated with the electrolytic corrosion due to stray electric currents is the electrolytic self corrosion, which is under some circumstances very serious and which is often wrongly attributed to railway currents. Electrolytic boiler corrosion, and the corrosion of metal lath used in building, are other examples of the same thing. These are also being investigated, and will be the subjects of published reports.

Another subject of great practical importance that remains to be studied is the life hazard in electric practise, and the proper regulations by states and municipalities for the protection of the public. Much attention is given by the Board of Fire Underwriters to the question of fire hazard, and in protecting buildings from the fire risk much has been done incidentally to reduce the risk to life. But too little attention has been given to the protection of the public from high potential power and lighting circuits, and few cities or states have legislated on the subject. A thorough study of this question, made with the fullest cooperation of the electrical power companies and the manufacturers of insulating materials, would yield results of great practical value, and open the way to municipal and state regulation and inspection.

4. THE TESTING OF INSTRUMENTS AND MATERIALS

Instruments and materials are tested by the bureau for the various departments of

the federal government and for the states and state institutions free of charge. For municipalities and corporations and individuals fees are charged, which in most cases scarcely cover the actual cost of the test, but which are high enough to exclude tests of small importance. In some cases the bureau declines to make tests, as, for example, when it is believed that the proposed test would not settle the question at issue, or where the work would be incommensurate with the value of the result, or where the test is simple and could be done as well elsewhere, and, of course, whenever the facilities or experience of the bureau are not sufficient to warrant attempting the work, or where the work already on hand is too great to permit it. But with these cases excluded, there remains a great variety of tests in all divisions of the bureau, which are being done for the government and the public, and many of these tests are of great practical importance. The fees charged are smaller than they would be if the tests were not generally of value to others besides those who pay for them. Most private tests, indeed, are of public advantage. For example, it is of public concern that manufacturers of electrical instruments have their standards tested at the bureau, as this tends to insure greater accuracy in the instruments sold to the public, without adding appreciably to the cost. That electric lighting companies have their test meters and voltmeters standardized and gas companies have their meter provers and photometric or calorimetric standards tested is a matter of public concern, for it improves the service rendered to the public. If manufacturers of electrical machinery have insulating materials tested for resistance and dielectric strength, and sheet iron and castings tested for magnetic quality, and copper tested for conductivity, their customers get better machines, and the public better service.

Electrical instruments tested by the bureau include standards of resistance and electromotive force, and precision resistance apparatus of all kinds; condensers and inductances of various kinds used in laboratory measurements and in radiotelegraphy, both commercial and experimental; ammeters, voltmeters, wattmeters, watt-hour meters and many other kinds of measuring instruments, for direct or alternating current; instrument transformers for current and voltage, including those for very heavy currents and high voltages; magnetic instruments; photometers, and various kinds of photometric standards, electric and gas, locomotive headlights, including oil, acetylene and electric; signal lamps, street lamps, etc.

Materials tested include copper, aluminum and other wires used as conductors of electricity; manganin, constantin and other alloys for resistance, thermal electromotive force, etc.; iron and steel and other magnetic or slightly magnetic materials for permeability, hysteresis, coercive force, etc.; sheet steels for iron losses due to alternating magnetizations; insulating materials for instruments and electrical construction; electric lamps for candle power, efficiency and life, and for the quality of the light furnished; oils to be used in standard lamps or as illuminant or for signal purposes, etc.

These tests of instruments and materials are sometimes made for the purpose of seeing whether they conform to the specifications under which they are sold, sometimes for the information of the manufacturer of the given instrument or material, sometimes for the information of an intending purchaser, often for the purpose of restandardizing the instrument for regular service. A great deal of time is required to keep the equipment employed in testing

in good condition, in order that it may give accurate and trustworthy results, and to check measurements previously made. In most kinds of testing, not half the total cost of the work is due to the time required to make the actual observations and calculations. But that is an inevitable condition, which never can be otherwise. For, if the work is not thoroughly reliable, its value has disappeared.

One of the interesting phases of this testing work is the uniformity which in some cases it maintains throughout the country in the output of different companies and the service rendered by different agencies. Before the bureau began its photometric testing, the standard of candle power varied from ten to twenty per cent. between different companies. The 16 candle-power standard lamps of different manufacturers varied from 14.5 to 17 candles. A 20 candle-power gas lamp on the average gave less light than a 20 candle-power electric lamp, for the unit in the gas industry was based on a different standard and was smaller. Now the unit of candle-power is the same for gas and electric light, and every manufacturer and every lighting company is on the same basis, for all get their standards, directly or indirectly, from the bureau.

Often tests are made to settle disputes, either concerning the accuracy of instruments or concerning the performance of a machine sold under guarantee. The confidence that has frequently been expressed in the justness and impartiality of the bureau's decisions, when thus acting as a court of appeal, has been gratifying to the officers of the bureau.

5. COOPERATION WITH ENGINEERING SOCIETIES

The bureau cooperates with many engineering societies and foreign laboratories in the work of standardizing and unifying practise, defining terms and improving nomenclature, working out uniform specifications and methods of tests, etc. In this work the division of Electricity, Magnetism and Photometry comes especially into contact with the American Institute of Electrical Engineers, the Illuminating Engineering Society, the Society for the Testing of Materials, the American Committee of the International Electrotechnical Commission and the International Committee on Electrical Units and Standards. The bureau is represented on the council or committees of all of these bodies, and each year many subjects arise that come within the field of the bureau's activities, and in the handling of which its representatives can cooperate. Reference was made above to the new tables of resistance for annealed copper wire. Heretofore, the English, German and American tables have all been different, not only for resistivity, but also for temperature coefficient, and two different densities were in use. Through the efforts of two of the above-mentioned bodies and the Bureau of Standards acting together in the negotiations with foreign laboratories and scientific societies, we are assured in the near future of international uniformity in all these quantities. Much has been accomplished also in securing international uniformity in electrical units, a common photometric unit in England, France and America, in comparing and standardizing measurements of electrical and magnetic quantities between national laboratories, etc.

The preparation of standard specifications for various kinds of materials is an important work, in which the bureau cooperates with the engineering societies and with the departments of the government.

6. COOPERATION WITH THE DEPARTMENTS OF THE GOVERNMENT

In addition to its cooperation with the departments of the government in the direction just noticed, and in doing testing in considerable quantity, the bureau cooperates with the departments also in other ways. With the War and Navy departments it cooperates in experimental work on radio-telegraphy, and several rooms in the bureau's laboratory are occupied by representatives of the signal corps of the army, and of the Navy Department, in this work. The bureau also renders technical assistance to the Bureau of Navigation, of the Department of Commerce and Labor, which is charged with the administration of the law requiring all passenger ships carrying fifty passengers or more to be equipped with radio-telegraphic apparatus. Its traveling inspectors visit the lamp factories and inspect for the various departments of the government a million electric lamps a year, taking samples for life test at the bureau.

7. DISSEMINATION OF INFORMATION

In addition to the scientific and engineering papers published in the *Bulletin,* and in the Bureau's Technologic Series thirty-one circulars of information have been published by the bureau on a variety of subjects, and among these nine have been prepared by the Electrical Division, and several others are in preparation. Among those issued may be mentioned "Standard Specifications for Incandescent Lamps," "A Proposed International Unit of Light," "Magnetic Testing," "Testing of Electrical Measuring Instruments," "Precision Measurements of Resistance and Electromotive Force" and "Transformer Specifications."

A large amount of time is expended in answering letters which request information. These come from many classes of inquirers, asking many kinds of questions, some very easy and some very hard to answer. All receive careful attention, no matter how humble the writer or how simple the question. We in our turn write a great many letters asking for information, and we have to acknowledge the uniform courtesy accorded to such inquiries, and the valuable information often so obtained.

Much information is communicated also to those who call personally at the bureau, and this is naturally an increasing quantity. As the apparatus, methods of measurement and results for the most part are open to the public, many find it advantageous to make personal visits. An exception is made as to the results of tests for which a fee is paid, these being held as confidential and communicated only with the consent of the person for whom the test was made.

Enough has been said to show the great variety of the work in one division of the bureau, which may be taken as typical of all. It extends from the purely scientific investigations on the one hand to the most practical of engineering problems on the other. The work in electricity, magnetism and photometry is distributed among three different buildings, and needs more space. The new building now under construction, which will be 190 × 60 feet in floor area, with four stories and basement, will afford larger and better accommodations for this work.

In closing this necessarily incomplete account of the work of the electrical division of the bureau, let me say a few words as to the reasons for testing instruments and materials purchased by the government. Most people admit the advantage of such testing, but few appreciate how important it is, or how many sided is the question of

testing in connection with government purchases. It is of importance from a business standpoint, and as a matter of good engineering. It is also of great importance as contributing to good government.

8. REASONS FOR TESTING MATERIALS PURCHASED BY THE GOVERNMENT

1. The first and most obvious reason for testing instruments, machinery and materials purchased by the federal government is of course to insure the government getting what it pays for. But that is not the only reason, and in some cases it may not be the main reason. Such testing is done upon many kinds of materials, but for a concrete illustration we may think of electrical instruments or electric lamps.

(1) With the results of a thorough and impartial test at hand, a government engineer, charged with drawing specifications for a given kind of instrument or material, knows what performance can be secured by such instruments, or what properties can be expected in the given material, and hence is able to prepare the specifications intelligently.

(2) With the results at hand of tests on the instruments or materials of different makes, the purchasing officer knows what makers to invite to submit bids for government requirements. If those whose instruments or materials are unsuited for the given purpose are not permitted to bid, expense and trouble are avoided, both to the manufacturer and to the government.

(3) If the results of thorough tests are available, the purchasing officer can take account of the quality as well as the price in making awards of contracts. It often happens that any one of several makes of instruments or materials can be used, and it is necessary to know the differences in quality as well as the differences in price in order to determine which bid is best. The practise of accepting the lowest bid regardless of quality often causes dissatisfaction both to those who bid for the government's business and those who use the articles purchased.

(4) If tests are systematically made, a conscientious purchasing officer is protected from charges of favoritism or collusion in the performance of his duty. His answer to such intimations, whether they come from dealers or those in authority, is the certified results of tests upon which he had relied. If the tests have been made in an impartial and well-equipped laboratory established for the purpose, the results are likely to be given greater weight, and the protection to the purchasing officer is greater, than if done by the bureau or department making the purchase. Purchasing under such a system of testing, the opportunity and the temptation to collusion between purchasing officer and contractor is greatly reduced. Such collusion is not frequent in the government service, but it has occurred, and it is desirable to reduce the opportunity for it to a minimum.

(5) Purchasing under a system of thorough and systematic tests protects administrative and purchasing officers from political pressure in connection with purchases, and members of congress are spared from the appeals of constituents in connection therewith. It has sometimes happened that a manufacturer or contractor on failing to secure a government contract feels that he has been discriminated against, and in good faith goes to his congressman or senator with his grievance. The latter is placed in an embarrassing position, between his desire to serve his constituent and his uncertainty as to the real facts in the case. A system of fair and thorough testing of materials in connection with public advertising removes almost entirely

any occasion for appealing to a member of the legislative branch of the government concerning business transactions in the executive departments.

(6) If the instruments or materials are delivered from time to time, tests are necessary in order to see that the deliveries are in accordance with the samples or the specifications. If deliveries are accepted without tests or inspection, or with inspection only, the door is opened for deception and fraud; honest dealers or manufacturers are at a disadvantage in competition with unscrupulous ones in dealing with the government; and it may result under such circumstances that the most reliable manufacturers will refrain from bidding on government business, leaving those who are willing to misrepresent their products to compete with one another for the government patronage. The government then becomes a party to fraudulent transactions, and to a greater or less extent tends to demoralize business. On the other hand, if careful inspections and tests are regularly made, and acceptances are conditioned on meeting the specifications, manufacturers often thereby become better acquainted with the properties of their own products, honesty and uprightness in business are encouraged, a standard of quality is set for the given instrument or material which helps other purchasers besides the government, and the whole industry may be greatly benefited.

(7) If the reports of such tests are communicated to the manufacturers, as they generally are, defects in the product are perhaps sooner discovered and sooner remedied, and if the government invites the cooperation of the manufacturers when undertaking tests of types of instruments or of materials, the tests are likely to be fairly conducted and the results representative.

(8) In these days of commercial combinations and gentlemen's agreements as to prices, it sometimes happens that the government can not secure competition in price, but finds that the bids from different manufacturers are identical in price. Here again, testing the product solves an otherwise serious difficulty, for it is generally possible even in this case to secure real competition as to quality, and this is quite as important as competition in price.

It is thus seen that there are many reasons for testing the thousands of kinds of instruments, machines and materials purchased by the government, and for doing this, in large measure at least, in a well-equipped institution set apart for that purpose. The Bureau of Standards has done considerable work of this kind, but the government's purchases are so varied and so vast, and so many requests for tests came from states, municipalities, and the public, that the work involved is very great, and only a fraction of the work is done which could be done with profit. Whether the bureau shall grow in the future as fast as the demands upon it for testing and investigation increase is uncertain. But if it does only a part of the work waiting to be done, and does that part well, it will amply justify its existence, and in so doing save the government and benefit the industries far more than the cost of its maintenance.

EDWARD B. ROSA
BUREAU OF STANDARDS

PROGRESS IN INDUSTRIAL FELLOWSHIPS

IN the issue of SCIENCE for Friday, May 7, 1909, I presented the main outlines and contemporary status of a scheme of industrial fellowships initiated by me in an article in the *North American Review* for May, 1907. Since this statement I have made no report to this journal.

I now present the establishment of a new